PB89-124457

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(U.S.) Environmental Protection Agency
Research Triangle Park, NC

Nov 88

U.S. Department of Commerce
National Technical Information Service

PB89-124457

EPA/600/D-88/235
November 1988

STATIONARY SOURCE CHARACTERIZATION AND CONTROL STRATEGIES FOR REACTIVE VOLATILE ORGANIC COMPOUNDS

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U.S. DEPARTMENT OF COMMERCE
NATIONAL TECHNICAL INFORMATION SERVICE
SPRINGFIELD, VA. 22161

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA/600/D-88/235	2.
3. RECIPIENT'S ACCESSION NO. PB89 124457/AS	
4. TITLE AND SUBTITLE Stationary Source Characterization and Control Strategies for Reactive Volatile Organic Compounds	5. REPORT DATE November 1988
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) G. Blair Martin	8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS See Block 12	10. PROGRAM ELEMENT NO.
	11. CONTRACT/GRANT NO. NA (Inhouse)
12. SPONSORING AGENCY NAME AND ADDRESS EPA, Office of Research and Development, Air and Energy Engineering Research Laboratory, Research Triangle Park, NC 27711	13. TYPE OF REPORT AND PERIOD COVERED Published paper
	14. SPONSORING AGENCY CODE EPA/600/13

15. SUPPLEMENTARY NOTES AEERL project officer is G. Blair Martin, Mail Drop 60, 919/541-7504.

16. ABSTRACT The paper provides a brief overview of the sources of volatile organic compounds (VOCs) and of the control technologies which may be used to control these emissions. VOCs are emitted to the atmosphere from a variety of processes. These compounds may react in the lower atmosphere as part of the process leading to ozone generation and/or may be classified as hazardous air pollutants (HAPs) which have direct health impacts.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Pollution	Pollution Control	13B
Organic Compounds	Stationary Sources	07C
Volatility	Volatile Organic Compounds (VOCs)	20M
Analyzing		14B
Properties	Hazardous Air Pollutants	14G
Ozone		07B
Toxicity		06T

18. DISTRIBUTION STATEMENT Release to Public	19. SECURITY CLASS (This Report) Unclassified	21. NO. OF PAGES 9
	20. SECURITY CLASS (This page) Unclassified	22. PRICE PC $10.95 / MF $6.95

EPA Form 2220-1 (9-73)

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ABSTRACT

Volatile organic compounds (VOCs) are emitted to the atmosphere from a variety of processes. These compounds may react in the lower atmosphere as part of the process leading to ozone generation and/or may be classified as hazardous air pollutants (HAPs) which have direct health impacts. This paper provides a brief overview of the sources of VOCs and of the control technologies which may be used to control these emissions.

INTRODUCTION

Volatile organic compounds (VOCs) are emitted by a wide variety of stationary and mobile sources. The vast majority of mobile source VOC emissions are from highway vehicles. The stationary emission sources are extremely varied ranging from large point sources to numerous relatively small area sources and fugitive emissions.

The major stationary source classes of VOCs are: solvent uses; petroleum production; treatment, storage, and disposal facilities; combustion; and industrial processes. Solvent uses include: metal cleaning, consumer solvents, and a variety of surfacing coatings. Petroleum production includes exploration, refinery processes, distribution, and marketing. Combustion includes numerous small fuel combustion processes and agricultural, forest, or other open burning. Industrial processes include organic chemical manufacturing and manufacturing of a number of consumer products. The specific process within these source categories will determine the applicable control technology. Many of the area and fugitive sources require a collection system of some kind to duct the VOC emission stream to the control device.

CONTROL TECHNOLOGY SELECTION

The control technologies applicable to control of VOC emissions are described in "Control Technologies for Hazardous Air Pollutants" (ref. 1), and a methodology for matching a specific source with a technology is discussed. Although the report deals with hazardous organics, the discussion of organic control technologies is equally applicable to all VOCs.

VOC Emission Characteristics

The characteristics of the VOC emission stream are more important in selection of the control technology than the type of source. These charac-

teristics can further be separated into two categories: stream characteristics and VOC characteristics.

Stream characteristics. The characteristics of the VOC-containing stream are a primary consideration in selecting the preferred control technology. The major stream characteristics are:

1. Organic content. The amount of VOC in the emission stream will determine whether the VOC can be economically recovered or if a destruction technology is preferred. It may also determine which type of combustion technology is preferred to most effectively and economically destroy the VOC.
2. Heat content. The heat content (Btu/SCF) of the stream is important primarily for those technologies where additional fuel may not be used in the combustion process (e.g., boilers or flares).
3. Moisture content. This characteristic is of primary importance only for carbon absorption.
4. Flow rate. The various technologies have different limits on the amount of flow that they can effectively handle. Additionally some of the technologies can handle time variant flow rates more effectively.

VOC characteristics. The characteristics of specific VOCs in the stream are important primarily for removal techniques. Molecular weight and adsorption/desorption characteristics are important for carbon adsorption. Solubility in water or other solvents is key for adsorbers. Vapor pressure as a function of temperature is the governing characteristic for condensers.

Control Technology Characteristics

Several control technologies are available to treat specific VOC streams. These technologies can be divided into two categories: destruction techniques and removal techniques.

Destruction techniques. All the currently available destruction techniques are based on combustion of the VOC stream either alone or with supplementary fuel. By matching the characteristics of the stream to the capabilities of the technologies, appropriate levels of control can be achieved at reasonable costs. The characteristics of each technology are:

1. Thermal incineration. This technique is broadly applicable to continuous VOC emission streams. It can achieve 95 to over 99% destruction relatively independent of VOC characteristics. Only minor fluctuation in flows can be tolerated and still maintain residence time and temperature necessary for high destruction

efficiency. Thermal incineration is typically applied to dilute mixtures of VOC and air at less than 25% of the lower explosive limit (LEL) concentration; however, if the VOC concentration is too low, supplemental fuel may be required to maintain the temperature necessary for acceptable destruction efficiency. A potential advantage is that systems which recover heat may allow recovery of some economic value.

2. Catalytic Incineration. This is another form of thermal incineration, which uses a catalyst to promote VOC oxidation at a lower temperature. It can achieve 90 to over 99% destruction of VOCs for low VOC concentrations. Its applicability is more restricted since VOC characteristics have a greater influence on the efficiency of the catalyst than for thermal incinerators. A number of metals, as well as sulfur and halogens, can poison the catalyst and reduce its efficiency. Careful temperature control is essential since the catalyst life can also be significantly reduced by thermal aging. In fact, catalyst life is a key factor both in maintaining control efficiency and in determining the economic feasibility of the technique. It has the advantage that the amount of supplemental fuel required may be reduced substantially.

3. Flares. Flares are typically used to control intermittent emissions during process upsets and/or emergencies. Properly designed flares for high heat content waste streams (>300 Btu/SCF or 1.12 megajoules per normal cubic meter) can achieve up to 98% VOC control. For lower heat content streams, supplemental fuel may be required. A variety of flare designs can accommodate a wide range of VOC stream characteristics and/or flow rates.

4. Boilers/Process Heaters. In many cases existing plant equipment can be used to destroy VOC streams and to recover energy at the same time. Destruction efficiencies of greater than 98% can be achieved. The limitation of the technology is the amount of a dilute VOC waste stream that can be incinerated without adversely affecting the equipment's primary function of supplying steam and/or heat to the plant.

Removal techniques. These techniques can provide efficient removal of the VOC from the emission stream but do not change the chemical form of the VOC. This has the advantage that economic product recovery may be achieved in addition to pollution control. Unlike

thermal destruction, these processes work on several different principles and can be strongly dependent on the VOC characteristics.

1. Carbon Adsorption. The VOC is selectively removed from the emission stream by a bed of activated carbon. Removal efficiencies of 50 to 99% can be achieved for dilute mixtures of VOC and air. Inlet VOC concentrations are limited to avoid exceeding the adsorption capacity of the bed and/or generating excessive bed temperatures due to the heat of adsorption. The maximum concentration is about 10,000 ppmv, and higher concentrations may have to be reduced by dilution. A further limitation may be placed on concentration of flammable organic vapors for safety reasons. These limits are 25% of LEL for most cases, although 40 to 50% of LEL may be acceptable if proper monitors and controls are present. Furthermore, high molecular weight organics may be difficult to remove from the bed once adsorbed. Therefore, the application of this technique is generally limited to compounds with boiling points less than 400° F (200° C) and/or molecular weights less than 130. On the other hand, compounds with molecular weights below 50 are not efficiently removed. Finally, the removal efficiency decreases as relative humidity increases and, at relative humidities above 50%, efficiency may show a significant decrease. In most systems one bed is used to adsorb organics from the stream while a second bed is being regenerated to recover a high VOC concentration stream.

2. Absorbers. This technique has limited applicability to organic vapors, although removal efficiencies can exceed 99% for specific systems. The primary limitation is the availability of a suitable solvent to remove the specific VOC. In addition, disposal of the used solvent can present additional problems.

3. Condensers. This technique is frequently used for recovery of raw materials and/or products from a process stream. Condensers are most suited to streams with more than 5000 ppmv and can achieve removal efficiencies increasing from 50 to 90% as VOC concentration increases. The VOC removal is limited by the VOC vapor pressure at the available coolant temperature. High removals require coolant temperatures below normal water temperature. Condensers can be used as a preliminary resource recovery and pollution control device to be followed by a destruction technique

for high efficiency. These devices are typically applicable to relatively low flow rates.

Computer Technique

Based on the HAP manual (ref.2), the EPA and the New Jersey Department of Environmental Protection have computerized the design and cost calculations for eight control devices for permit reviewers. This program, called Controlling Air Toxics (CAT), has been designed for use on IBM compatible computers. Information supplied on the permit application is entered into the program, and design parameters and cost estimates are calculated. The program is designed to easily perform what-if calculations, allowing the reviewer to change parameters and quickly see the impact on design and costs.

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1 Control Technologies for Hazardous Air Pollutants, EPA/625/6-86/014, September 1986.
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